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Abstract **:** *Vehicular Ad-hoc NETworks (VANETs) are mainly evaluated through simulations in which the choice of a realistic wireless channel model is a central point. Deterministic channel models bring good realism but need huge simulation time, whereas with statistical models the computational effort is reduced, but sadly so is the realism of the model. In this paper, we present a semi-deterministic channel model, called UM-CRT, based on a deterministic channel simulator, CRT (Communication Ray Tracer) and a statistical channel model, SCME–UM (Spatial Channel Model Extended – Urban Microcell). To integrate it into the NS-2 network simulator, we couple it to self-developed fully compliant 802.11p and 802.11n physical layers. Simulations in urban environment show both a good realism and a reduced computation time indicating that UM-CRT is adapted for VANETs simulations.*

INTRODUCTION

With the strong impact of vehicular communications in the areas of safety, energy conservation and entertainment, Vehicular Ad-hoc Networks (VANETs) is currently a hot topic for the scientific community, car manufacturers and mobile telephony operators.
However, due to the specific characteristics of this type of communication such as high mobility and changes in the surrounding environment, the conventional simulation tools used in networking must be adapted.
Many research and development works relating to routing [1], communication robustness [2], information dissemination [3] show results obtained with simulations involving very simplistic radio propagation models available in simulation tools. Some research works take into account the effects of the propagation model in VANETs simulations e.g. [4]. Moreover, only few work study the improvements brought by the 802.11p standard aimed at enhancements to Intelligent Transportation Systems. These papers indicate that the realism of the propagation model has a negative effect on the percentage of received packets. From this, we can conclude that realistic propagation models are a key for VANETs simulations.
The vast majority of network simulators allow the simulation of nodes' mobility. However, the consequence of this mobility on the physical layer is most of the time treated in a simplistic and consequently not quite realistic manner. This can lead to erroneous results [4]. Moreover, one finds very few effective and robust channel models which take into account the mobility and especially the transmission environment.

The rest of the paper is organized as follow. In Section 1, we briefly present several approaches of channel modeling and different VANETs simulators. To simulate with realism a vehicular ad-hoc network and to evaluate its performance in a specific environment, a proposed solution is described in section 2. It is based on a semi-deterministic channel model and the IEEE 802.11 p and n physical layers. Finally, section 3 concludes the paper and deals with future works.

1. Channel and mobility modeling for VANETS simulations

Channel modeling

The radio propagation model used by a network simulation tool is a key factor in MANETs (Mobile Ad Hoc NETworks) and particularly in the VANETs subclass. Developing a radio channel model, which would describe the realistic radio channel conditions as accurately as possible, has been a continuous challenge. Significant scientific contributions given by numerous researchers over the years enabled further, more profound and more specific analysis of the certain phenomena, which gives more accurate description, often at the price of increased complexity.

There exist reliable channel models, which are customizable according to the environment [5], but most of them are dedicated to mobile telephony. In parallel, one finds research works presenting deterministic channel models [6], which are based on ray-tracing or ray-launching methods, which allow a realistic modeling of the channel. Unfortunately, these models require very high processing times.

In reference [7] Hamidouche et al. study the impact of a realistic physical layer on the H.264/AVC video transmission over Ad Hoc networks in an urban environment. Their results show significant differences between the Quality of Services (QoS) of H.264/AVC video transmission obtained with respectively an empirical and a realistic physical layers model. They also propose an error model based on a Bit Error Rate (BER) computation.

As far as VANETs are concerned, deterministic channel models are not suitable because of the high mobility, the diversity of the situations encountered and the high number of communicating nodes. The study of the higher layers of the OSI model (in particular the Network and Application layers) requires a low simulation time (i.e. a couple of minutes) in order to allow statistical analyses on large simulation series. Moreover, in order to simulate VANETs efficiently, one must have a network simulator, which takes into account the mobility associated with the modeling of the realistic physical layer and which is also efficient in terms of processing time. To answer the challenge of channel modeling in VANETs, several works propose various methods, which can be classified in two categories according to the research domain of their authors.

In the network community, Dhoutaut et al. [8] propose a propagation model based on Markov chains elements and real world experiments which is able to generate packet losses in a very realistic way. Later on, SeonYeong Han et al. proposed an other method based on Finite State Markov Channel [9]. These models are half-way between very detailed models using ray-tracing with computationally intensive algorithms and models using theoretical analysis where physical phenomena are only handled in an aggregate manner. But according to the authors, their models are not yet able to make a clear relation with a real environment.

In the physical channel modeling community, one can find different statistical channel models which have been derived from measurement campaigns. The 802.11p channel model is based on the work of Acosta-Marum et al [10][11]. It is a classical tapped delay line Wide Sense Stationary Uncorrelated Scattering (WSSUS) channel model. However, several research works have shown that in many situations the vehicular channel cannot be considered as stationary [12]. Moreover, correlation is present between the Channel Impulse Response (CIR) taps and therefore the US assumption does not hold. To address this problem several authors have proposed solutions to take into account the non-stationary nature of the vehicular channel. Hence, in reference [13] Sen et al. propose channel models which take into account the sudden appearance/disappearance of scatterers (moving obstacles) by modeling them as first order two-state Markov chains. Surprisingly, their results show that the WSSUS assumption gives the worst case situation when it is compared to their non-stationary models. In reference [14] Keredal et al. propose a geometry based stochastic MIMO model for Vehicle-To-Vehicle (VTV) communications. The position of the scatterers and their persistence in the scene can be parametrized according to the environment. However, as stated by Molisch in [12], there is only a small amount of VTV channel measurements available, which

"does not allow the derivation of statistically significant statements about real-world VTV channels". In conclusion, extreme care has to be taken when choosing and parameterizing available statistical channel models for VANETs.
To answer all of these issues, we propose a semi-deterministic channel model called UM-CRT. It is based on the statistical Spatial Channel Model Extended Urban Microcell [15] developed for the Beyond 3G technology (B3G) and a deterministic propagation simulator called Communication Ray Tracer (CRT) developed by the Xlim-SIC laboratory in Poitiers-France [16]. More about this model in section 2.

Mobility modeling for VANET simulations

Another fundamental topic in VANETs simulation concerns the mobility model used in simulations. Many works show the importance of realistic mobility models. Indeed, the use of non-specific mobility models employed in VANETs simulations may provide bad results, because they ignore the special behavior of the nodes through this kind of network.
Therefore, there are two main challenges on the way to more realistic simulations of vehicular mobile ad-hoc networks: the use of sophisticated radio wave propagation models and the introduction of realistic mobility of vehicles. Both have strong impact on the performance of mobile ad-hoc networks, e.g. the performance of routing protocols changes a lot according to these factors. Many works try to answer this challenge. Most mobility models can now take into account both macro-mobility and micro-mobility features, and network simulators also improved for VANETs simulations. Therefore, a combination of realistic radio wave propagation models and realistic mobility models is a large step towards more realistic VANETs simulation environments as shown by Günes et al. [17].
In this work, the selected simulation tool are the VANET specific mobility generator VanetMobiSim [18] and the generic network simulation tool NS-2. VanetMobiSim is used for creating mobility models as close as possible to realistic vehicular mobility, resulting in an NS-2 trace file. Then, NS-2 simulates the network communications. The main advantages of using this approach are that we use a validated mobility model generator and a widely accepted network simulator. When used with our realistic propagation model, we have all the components to reach a sufficient level of realism to confidently simulate VANETs.

2. A REALISTIC VANET SIMULATOR

The setup of the realistic vanet simulator

We started this work by designing a realistic VANET simulator because we noticed that many simulations reported in the wireless networking literature contained simplistic abstractions of the physical layer, which lead to erroneous results. This work is therefore an attempt to "bridge the gap between physical layer emulation and network simulation" [19].

In reference [20], we propose a semi-deterministic channel model called UM-CRT, which uses a deterministic propagation simulator called Communication Ray Tracer (CRT) together with the Spatial Channel Model Extended (SCME) statistical channel model [5]. The SCME describes three different environments. The Urban Microcell (UM) scenario has been selected because it considers communication distances of less than one kilometer, which is common in VANET urban situations. We also used the error model presented in [7] into our model-building process.

Classically, for all radio links existing between nodes, on the one hand, CRT computes CIRs according to the simulation of all the received multi-paths according to an environment modeled in 3D. On the other hand, SCME-UM provides statistically generated CIRs. On this basis, it is possible to generate representative CIRs with SCME-UM.

The CIRs obtained by CRT are used to determine if we are in a LOS or NLOS situation and then parameterize the SCME-UM statistical channel model. Because UM-CRT is born from the merging of two other models, the best way to describe it is to explain thoroughly its simulation procedure. Figure 1 depicts UM-CRT with dashed arrows.

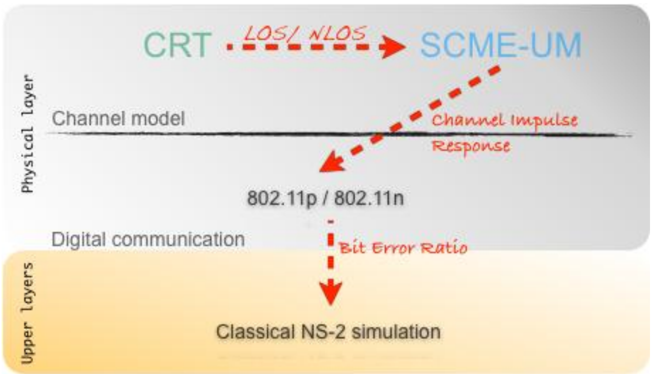

Figure 1: The UM-CRT framework

The simulation works in two steps. The first step consists in a pre-processing stage. The second step only consists in the determination of the LOS-NLOS criterion, then reading the corresponding SCME-UM CIR coefficients according to the distance between the transmitter and the receiver.

In order to evaluate this model in VANET situations, it has been integrated in the network simulator NS-2. Fully compliant 802.11p and 802.11n physical layers using the IT++ library have also been implemented. We have performed simulations in SISO and MIMO modes in the 5 GHz band. In order to have some typical cases for comparing UM-CRT to CRT, four representative urban mobility scenarios have been generated by VanetMobiSim [18].

The evaluation of the realistic VANET simulator

To evaluate our propagation model, which is associated with a realistic mobiliy model, we compare it with the CRT simulator using NS-2 simulations in a typical urban environment. As mentioned above, CRT will be our reference model and can be considered realistic enough to match real world implementation results. Remember that our main goal is to evaluate the agreement of the results of UM-CRT and CRT in every situation.

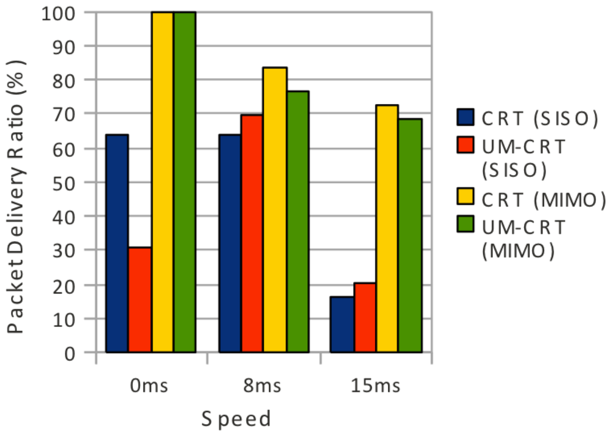

Figure 2: PDR with UM-CRT and CRT in SISO and MIMO configuration

Figure 2 shows the results in terms of Packet Delivery Ratio (PDR) obtained for one scenario in the SISO and the MIMO cases. One can observe that the semi-deterministic model (UM-CRT) comes very close to the deterministic channel simulator (CRT). As expected, one can also notice the significant improvement brought by the 2 x 2 MIMO configuration (Alamouti scheme).

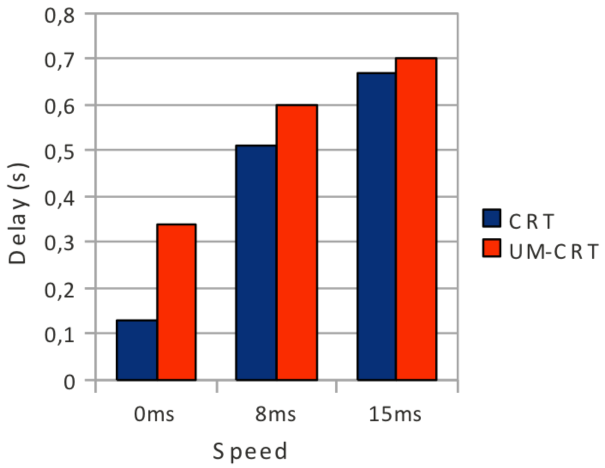

Figure 3 : Propagation delay with UM-CRT and CRT

Figure 3 confirms the trend observed in Figure 2. If we look further, the similarity between the two models can be observed through the average delay gap reduction when the speed increases. For this parameter, the difference between the two models can be considered very small, except for static situations.

Furthermore, as the speed increases, one can see that the channel deteriorates (the received packets rate decreases) and that it is more difficult to achieve a reliable communication (the delay increases). This is a second expression of the determinism of our statistically-based model.

3. CONCLUSIONS

In this paper, through the analysis of several research works, we have highlighted the impact of realism on both the channel propagation model and the mobility model used in VANETs simulations.

We have implemented realistic VANET simulations by using vehicular mobility traces generated with the VanetMobiSim tool. The realism of the channel propagation model was obtained thanks to a new hybrid channel model for VANETs based on the stochastic SCME-UM model and the deterministic CRT channel simulator. These elements have been integrated into the NS-2 network simulator.

To evaluate this new model, we have compared it to the CRT simulator which is a fully deterministic model. Our simulations have shown that this new model closely approximates the propagation delay results obtained with the deterministic simulator and is therefore suitable for realistic VANETs simulations.

Because the UM-CRT model is also MIMO capable, it has also been evaluated with this feature. Results found in MIMO situations improve significantly compared to those found in SISO situations (e.g. PDR). We therefore believe that MIMO is probably going to be a natural evolution of the 802.11p standard.

Finally, many topics remain open. Indeed, the small amount of available V2V measurements does not allow the formulation of statistically significant statements about real-world V2V channels. Moreover, VANET environments characteristics vary regionally. VANET measurement campaigns have therefore to be performed in different parts of the world if one wants to develop an accurate statistical channel model for VANETs (as it has been the case for mobile telephony).

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